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Nr. 10. Baggesgaard-Rasmussen and J. P. Jacobsen: CONTRIBUTION TO THE HYDROGRAPHY OF THE WATERS ROUND GREENLAND IN THE YEAR 1925

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
1930

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CONTRIBUTION TO THE HYDROGRAPHY OF THE WATERS ROUND GREENLAND IN THE YEAR 1925

BY

BAGGESGAARD-RASMUSSEN AND J. P. JACOBSEN

KØBENHAVN
C. A. REITZELS FORLAG
BIANCO LUNOS BOGTRYKKERI A/S
1930

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Introduction.

In the present paper we propose to survey the hydrographical conditions in the southern parts of Denmark Strait and in the waters off the west coast of Greenland, as they appeared during the expedition of the Danish investigation ship "Dana" sent out in 1925 by "Kommissionen for Fiskeri- og Havundersøgelser".

The observations, consisting in measurements of the temperature, salinity, amount of oxygen, and hydrogen ion concentration, were carried out onboard by one of us (Baggesgaard-Rasmussen), and have

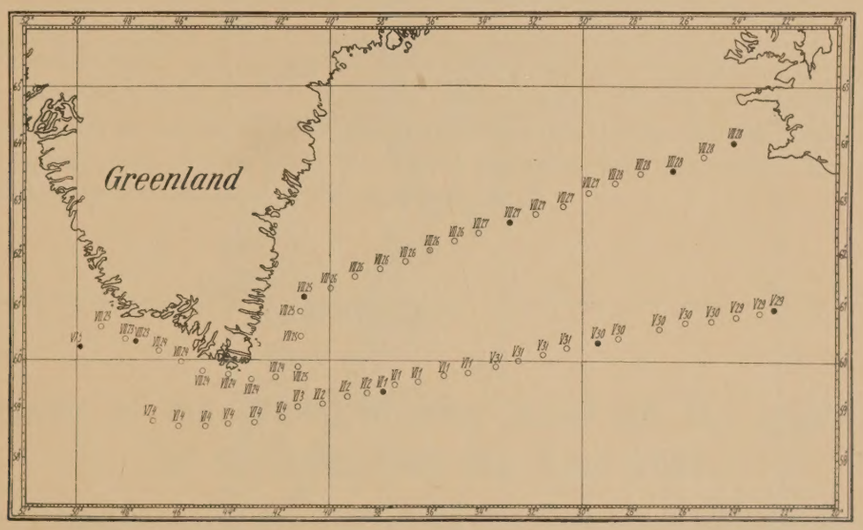

Fig. 1. Chart of the routes of the "Dana" to and from Greenland in 1925. The filled circles represent stations where measurements were taken in the deeper layers. The open circles represent surface observations. All the stations are marked with the date at which they were taken.

been published in the Bulletin hydrographique pour l'année 1925, edited by the "Service hydrographique" of the International Council for the Exploration of the Sea. The areas investigated are shown on the charts in figs. 1 and 2. On the chart in fig. 1 observations from stations with measurements from different depths have been plotted as dots, whereas places where surface samples only were taken have been plotted as small circles. On the chart in fig. 2 only the stations are plotted. Each place of observation is marked with the date at which the observations were taken.

Besides these observations from the "Dana" we have also made use of some observations taken in 1925 from the surveying vessel "Islands Falk" by Commander Riis-Carstensen, and further of some surface observations taken in 1925 from the ships of "Kgl. grønlandske Handel". These observations, too, will be found in the Bulletin hydrographique.

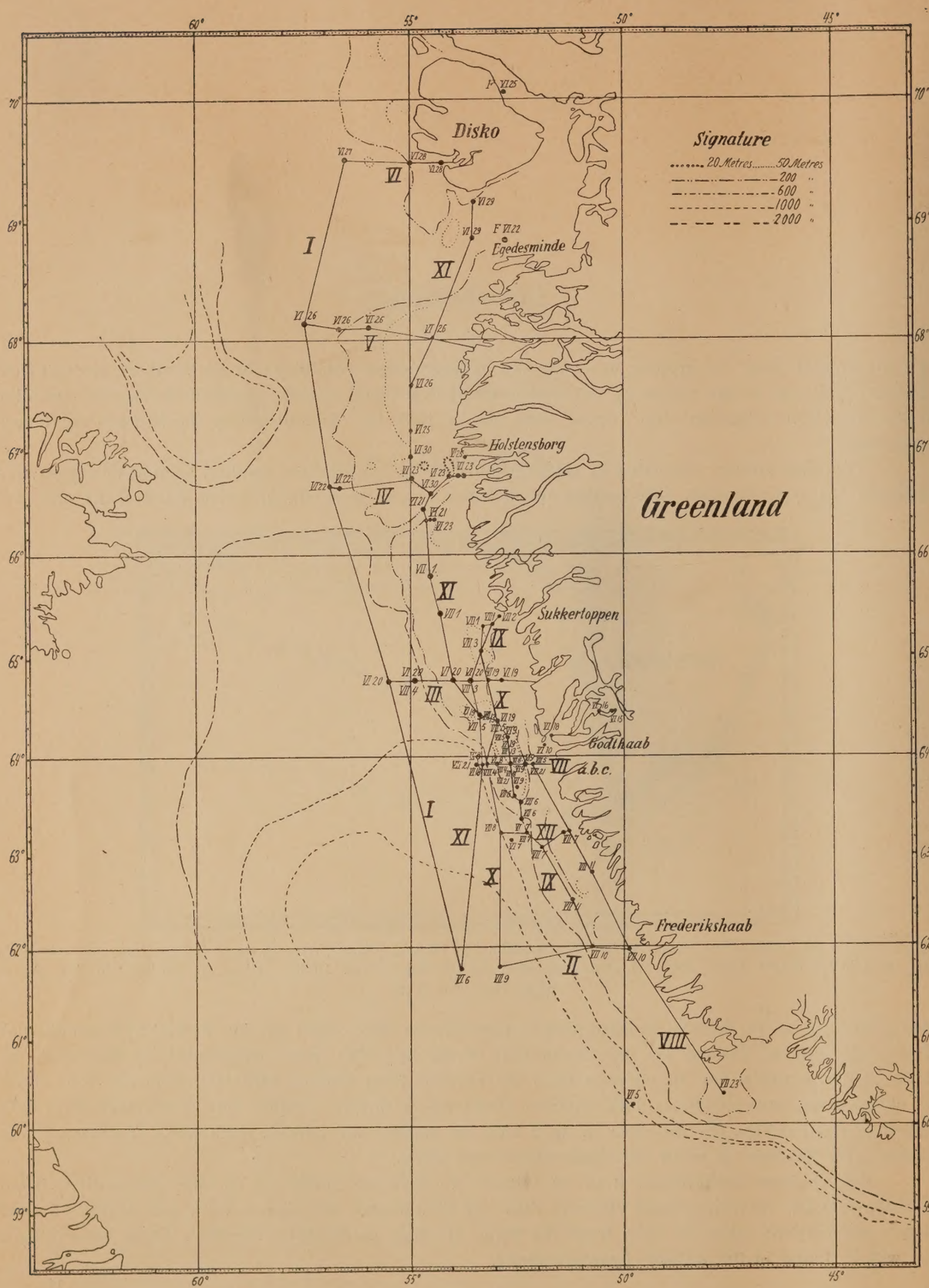

Fig. 2. Chart of the stations of the "Dana" with measurements in the deeper layers from the expedition in Greenlandish waters in 1925. The stations are marked with the date at which they were taken. The lines marked with Roman numerals represent sections mentioned in this paper.

It is a fact well known from earlier investigations that water from the East Greenland Polar current passes round the southern coast of Greenland and penetrates into Davis Strait, carrying with it in the spring and early summer the "Storis" (field ice), as far as to the latitude of Godthaab or thereabouts. A description of the currents in these waters has been given by LUDVIG MECKING[1]).

The Polar current makes itself felt in Davis Strait by the cold water present at depths from c. 25 to 100 or 150 meters with a minimum temperature approaching 0 degrees.

Below the cold water originating from the Polar current there occurs in Davis Strait a warmer layer having a temperature of c. 4°, predominant at c. 400 meters' depth. It originates from the upper layers of the Atlantic water in the southern parts of Denmark Strait. The outskirts of this intermediate layer of warm water also penetrate into Baffin Bay over the ridge in the narrowest part of the Strait, whereas the water from the Polar current is in the main deflected to the west before the ridge, and partly united with the southgoing current in the western parts of Davis Strait, partly intermixed with the water masses in the Strait.

Over the ridge and in Baffin Bay there also occurs a cold water-layer at c. 100 meters' depth with temperatures similar to those of the cold water-layer in Davis Strait, but with greater salinity. This water-layer may be supposed to have its origin in Baffin Bay.

The bottom water in Davis Strait, i. e. at depths below c. 1000 meters, may be assumed to have been formed in connection with the bottom water in the northern Atlantic and to have a temperature of c. 2°5 and a salinity of c. 34.90 ‰.

The above-mentioned general features of the hydrographical conditions in the waters under consideration have been dealt with by J. N. NIELSEN[2]) in his paper "The Waters round Greenland", and to this paper we may refer the reader as to earlier investigations and various questions which will not be considered here. Reference may also be made to a recent paper, by ERIK MARTENS[3]), dealing with the Norwegian investigations in Greenlandish waters in 1924.

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2. Examination of the Water Masses found off the south-west Coast of Greenland in the Year 1925.

a. Water originating in the main from the East Greenland Polar current.

As mentioned above, this water is predominant off the south-west coast of Greenland at depths from c. 25 to 150 meters. In order to define its qualities we shall make use of stations in the area from 60° to 63°30′ N. Lat. (see fig. 2) where a minimum temperature below 1° is found at an intermediate depth. From this limitation it follows that some of the stations situated in the area must be disregarded. These stations are given in table 1.

In table 2 the remaining stations are arranged according to their latitude, and, as stated in the table, the minimum temperatures are on an average found at a depth of 51 meters. The averages of temperature, salinity and content of oxygen at these depths are relatively —0°24, 33.42 ‰ and 97 %.

[1]) LUDVIG MECKING. Die Eistrift aus dem Bereich der Baffin Bai beherrscht von Strom und Wetter. Veröffentlichungen des Instituts für Meereskunde, Heft 7. Berlin 1906.

[2]) Greenland, Vol. I, published by the Commission for the Direction of the Geological and Geographical Investigations in Greenland. Copenhagen 1921.

[3]) Hydrographical Investigations during the "Michael Sars" Expedition 1924. Rapp. et Proc. Verb. Vol. LVI. Conseil international pour l'exploration de la mer. Copenhague 1929.

On closer examination of the figures in table 2 it will be found that the salinities increase from south to north and that they are a little higher in June than in July. The lowest temperatures are found in the northern part of the area. At the station VII. 7 (63°03′, 51°56′) the minimum temperature 0°05

Table 1.

Station	N. Lat.	W. Long.	Depth in the sea m.	Temperature at the bottom $t°$	Salinity at the bottom S ‰	Minimum Temperature		
						Depth	Temp.	Sal.
VII. 10	61°59′	50°45′	> 600	...	...	100	2.12	34.33
VII. 9	47′	52°55′	3020	...	...	25	3.86	.29
						75	.46	.67
VI. 5	60°13′	49°52′	2650	...	...	25	.00	.54
VII. 6	63°21′	52°24′	75	0.35	33.66	no intermediate minimum.		
VII. 7	13′	51°17′	56	.35	.42			
VI. 7	10′	52°20′	82	.17	.69			

is found at a depth of 35 meters, but no observation has been taken between 35 and 60 meters, and it is probable that the temperature would have been found lower at e. g. 50 meters. From a graphical interpolation the temperature at 50 meters can be estimated at —0°5, and the salinity at 33.62 ‰.

As the main features of the water in Davis Strait considered to originate mainly from the East Greenland Polar Current we may state that it occurs at c. 50 meters' depth with a temperature of —0°2, a salinity of 33.4 ‰, and an oxygen content of 97 %.

Table 2.

Station	N. Lat.	W. Long.	Depth in the sea m	Minimum Temperature			
				Depth m	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat %
VII. 7	63°13′	52°17′	105	75	0.18	33.62	(97)
VII. 8	13′	55′	> 1100	75	— 0.61	.62	(97)
VII. 7	13′	51°26′	162	75	— 0.03	.53	—
VI. 7	08′	52°40′	> 700	25	— 0.02	.57	85
VII. 7	03′	51°56′	70	35	0.05	.51	(97)
VII. 11	62°47′	50°47′	110	75	— 1.03	.28	(97)
VII. 11	30′	51°12′	91	25	— 1.01	.21	100
VII. 10	61°57′	49°55′	92 à 152	75	0.09	.17	101
VI. 6	47′	53°43′	> 2000	25	— 0.29	.62	97
VII. 23	60°20′	47°40′	150	25	0.26	.06	105
			Mean ...	51	— 0.24	33.42	97

On the east coast of Greenland the water of the East Greenland Polar current has a lower temperature (c. —1°) and a greater salinity (c. 34 ‰) than stated here. The increase of the temperature and decrease of the salinity may be accounted for by the intermixing of the water from the Polar current with the surrounding waters in Davis Strait. This may also explain some of the variations from the mean values found at the different stations. Possibly some of the very low temperatures may be due to local influences.

b. The cold Water on or near the Banks in the shallow Part of Davis Strait.

Whilst it must be assumed that the above-mentioned cold intermediate water-layer in the south-eastern part of Davis Strait mainly consists of water originating from the East Greenland Polar current, the same cannot be the case with the cold water-layer occurring at about the same depth (c. 100 meters) in the shallower part of Davis Strait. This cold water-layer may be supposed to have its origin from Baffin Bay where it has been formed during the winter in connection with the formation of the winter ice. After the melting away of the ice in the spring and the early summer this cold water forms an intermediate water-layer with lower temperatures and higher salinities than those of the cold water-layer in the southern part of Davis Strait.

Probably there may be a transitional area between the localities mentioned here and the southern part of Davis Strait influenced by the Polar current, so for the determination of the cold water-layer here considered we shall only make use of stations between 65° and 68°30′ N. Lat. (see fig. 2), and among these only of such for which the depth lies between 70 and 400 meters. The stations given in table 3 are disregarded.

Table 3.

Station	N. Lat.	W. Long.	Depth in the sea m.	Minimum Temperature		
				Depth m.	Temp. $t°$	Sal. S‰
VI. 23	66°45′	53°45′	420	300	— 0.64	34.18
VI. 22	38′	56°52′	...	100	0.56	.05
VI. 22	37′	37′	460	100	.60	.11
VI. 26	67°35′	55°00′	41	40	.56	33.91
VI. 25	10′	00′	53	50	.51	34.00
VI. 25	66°56′	53°42′	45	40	.58	33.98
VI. 23	44′	55′	67	50	.58	34.09
VI. 23	44′	54°06′	30	25	.01	.09
VII. 2	65°24′	52°56′	...	20	.68	33.57
VII. 3	03′	53°22′	63	60	.43	.96

At the two stations VI. 22 given in the table the intermediate cold water-layer has only to some slight degree influenced the temperature at 100 meters, which may be accounted for by a mixing with the deeper water-layers outside the banks. This explanation is supported by the fact that the temperature minimum —0°64 at the station 66°45′, 53°45′ is found at 300 meters' depth. This station lies in the inner part of the channel between the great and the little Hellefiskebanks, and waters with negative temperatures are found at all depths from 100 to 400 meters.

The rest of the stations mentioned in table 3 are all of small depth, and no water with negative temperatures is found, owing to the mixing of the cold water with the surface water heated by the sun.

For the purpose of determining the temperature and salinity of the cold water-layer at c. 100 meters' depth in the area between 65° and 68°30′ N. Lat. here considered, the remaining stations have been tabulated in table 4 and according to the means found in the table the characteristic temperature and salinity may be stated to be —0°7 and 34.1‰, and its depth put at 100 meters. The mean value of the oxygen of the water in question is found to be 95 %.

It is seen from the table that the temperatures and salinities and also the depths show a rather great deviation from the mean values. Possibly these deviations can in some degree be accounted for by the different positions of the stations viz. on the banks, on the slope of the banks, or in the channel

between the banks, in a similar way as indicated for the stations mentioned in table 3. Many deviations must however be due to accidental causes. The temperature and salinity characteristic of the cold water

Table 4.

Station	N. Lat.	W. Long.	Depth in the sea m.	Minimum Temperature			
				Depth m.	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat. %
VI. 26	68°08′	57°30′	398	50	— 0.64	33.89	87
VI. 26	05′	56°00′	149	50	— 1.15	34.05	
VI. 26	05′	41′	218	50	— 1.38	33.91	89
VI. 26	00′	54°30′	74	70	— 0.54	.96	97
VI. 30	66°56′	55°00′	94	90	— 0.66	34.16	104
VI. 23	41′	00′	98	90	— 0.15	.14	104
VI. 30	35′	54°32′	166	150	— 1.50	.38	91
VI. 21	28′	45′	165	150	— 0.32	.29	107
VI. 23	20′	30′	108	95	0.10	.18	96
VI. 21	17′	36′	97	90	— 0.04	.18	95
VI. 21	17′	38′	285	100	— 0.52	.22	100
VII. 1	65°47′	31′	124	100	— 0.39	.33	90
VII. 1	25′	15′	150	150	— 1.33	.36	87
VII. 1	20′	53°02′	220	200	— 0.99	33.86	95
VII. 1	19′	18′	170	100	— 0.93	.91	94
			Mean...	102	— 0.70	34.12	95

on the banks in the shallow part of Davis Strait are seen to differ from those of the cold water in the southern parts of Davis Strait. These differences account for the difference in the origin of the two cold water-layers.

c. The cold Water on or near the Banks in the Area between the Areas mentioned under a) and b) i. e. between Latitudes 63°30′ and 65° N.

As is generally known, the ice carried along the coast by the current has normally melted away in the spring before reaching the area mentioned here. This was also the case in 1925. After the melting away of the ice a more extensive heating of the surface takes place, and the mixing of the cold water-layer at c. 100 meters with heated surface water then causes the minimum temperature in water coming from the south to increase somewhat. This may especially be the case on the shallow banks; and when discussing the cold water found in the area, we shall disregard stations with depths less than 70 meters.

Besides the cold water coming from the south it may be presumed that cold water from Baffin Bay as mentioned under b) also occurs. The temperatures of this water may be a little lower than the temperatures of the water coming from the south, but this water, too, is relatively strongly heated on the shallow banks, and in regard to such water, too, it has been thought convenient to exclude stations with depths less than 70 meters.

The disregarded stations are given in table 5.

The influence of the summer heating is clearly seen for the stations at the same spot, taken at different dates from June 8th to July 21st. In this period the temperature at the bottom has risen from 0°38 to 2°74. The remaining stations with depths greater than 70 meters are given in table 6. Even at these stations summer heating has undoubtedly taken place, as may be seen e. g. in the case of the station at 63°56′ N. 52°15 W., where the temperature minimum has risen 1°4 from June 9th to July 21st

Table 5.

Station	N. Lat.	W. Long.	Depth in the sea m.	Temperature near the bottom			
				Depth m.	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat %
VII. 13	64°25′	53°24′	68	65	1.09	33.87	
VI. 9	11′	52°47′	50	40	0.24	.69	103
VII. 5	11′	47′	48	45	1.40	.58	101
FVI.28	02′	37′	38	36	90	.57	103
VI. 8	63°56′	41′	49	45	0.38	.69	109
VI. 9	56′	41′	..	50	47	.75	
VI. 18	56′	41′	48	45	1.06	.80	105
VII. 4	56′	41′	51	45	68	.57	101
VII. 13	56′	41′	44	40	2.09	.44	...
VII. 21	56′	41′	45	40	74	.17	103
VI. 9	40′	34′	52	50	0.82	.75	102
VII. 6	36′	34′	53	50	87	.40	102
			Mean...	46	1.23	33.61	103

and a little more at 100 meters' depth. Nevertheless we do not always find a rise in the temperature minimum when observations from the same spot at different dates are at hand; e. g. at 64°21′ N. 53°00′ W. the temperature at 200 meters was 0°09 on June 19th and —0°90 on July 5th. Thus it is seen that

Table 6.

Station	N. Lat.	W. Long.	Depth in the sea m.	Minimum Temperature			
				Depth m.	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat %
VI. 19	64°45′	52°52′	506	200	— 0.01	33.98	89
VI. 19	45′	53°13′	145	135	— 0.01	34.02	94
VI. 20	45′	36′	147	140	0.24	.13	91
VII. 3	45′	36′	123	100	.01	33.96	95
VI. 20	45′	54°00′	130	125	.28	34.13	90
VI. 20	45′	56′	490	75	.30	33.78	92
VII. 4	45′	56′	515	75	.00	34.04	92
VI. 20	45′	55°29′	920	75	.69	.18	(92)
VI. 19	25′	53°24′	73	70	.38	.14	95
VII. 5	25′	24′	89	80	.31	33.96	94
VI. 19	21′	00′	340	200	.09	34.33	95
VII. 5	21′	00′	288	200	— 0.90	.11	(92)
VI. 19	11′	52°47′	85	75	0.30	33.80	100
VI. 10	06′	51°56′	375	200	.57	.80	104
VI. 9	63°56′	52°15′	190	100	— 0.04	.71	93
VII. 5	56′	15′	230	75	0.36	.55	(96)
VII. 21	56′	15′	220	175	1.36	.71	89
VI. 9	56′	24′	85	75	0.69	.75	107
VI. 8	56′	53°00′	76	70	.20	.77	105
VII. 4	56′	14′	502	75	— 0.79	.87	94
VI. 8	56′	23′	> 1050	100	— 0.17	.80	101
VI. 18	56′	23′	930	100	0.20	.82	98
VII. 21	56′	30′	1090	100	.65	.82	97
VII. 6	31′	52°26′	383	100	.43	.77	
			Mean...	113	0.21	33.91	95

some allowance must be made for the deviations from the normal value of the temperature and also of the salinity, and probably such deviations should be greater for the area mentioned here than for the areas mentioned under a) og b).

The mean values for the temperatures and salinities at the depth where the temperature attains its minimum are seen to be 0°21 and 33.91 ‰, and the average of the depths for the temperature minimum is 113 meters.

d. The cold Water at 50—100 Meters on the Disco Plateau.

In this area we have only 5 stations (see fig. 2) from the "Dana" expedition in 1925, and the conditions found at these stations are very similar to those mentioned under b) for the little and great Hellefiskebanks. The minimum temperature lies at about the same depth as on the Hellefiskebanks, and the values of temperature and salinity at that depth are about the same. On the other hand, the amount of oxygen in the water with the lowest temperature seems to be considerably lower at the Disco plateau than on the Hellefiskebanks. This may be due to the fact that the surface layer on the Disco plateau has a lower salinity than on the Hellefiskebanks, and in greater degree prevents the mixing of the upper layers.

At all the stations given from the "Dana" expedition in 1925 there occurs cold water with negative temperatures. This is not the case with a station taken the same year in the same region at the surveying vessel "Islands Falk" by Commander Riis Carstensen. The station is marked F VI 22 on the chart in fig. 2. The depth at the station was 650 meters and the lowest temperature 0°81 was found at 100 meters. From the observations at station F VI 22 and station VI. 29 (68°52′, 53°32′) taken by the "Dana" with the temperature —0°51 at 75 meters' depth it will be seen that the occurrence of the cold water-layer may be somewhat variable.

In the same way as for the other areas table 7 gives the temperature, salinity and amount of oxygen for the depth at which the temperature is minimum at the stations here in question.

Table 7.

Station	N. Lat.	W. Long.	Depth in the sea m	Minimum Temperature			
				Depth m	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat. %
VI. 27	69°30′	56°32′	202	50	— 1.62	33.73	
VI. 28	28′	54°16′	65	65	— 0.10	.98	85
VI. 28	28′	55°00′	152	75	— 0.10	.93	83
VI. 29	10′	53°32′	280	75	— 0.20	34.00	80
VI. 29	68°52′	32′	775	75	— 0.51	.18	84
			Mean...	68	— 0.51	33.96	83

Comparing the mean values in table 7 with those of table 4 we see, as was previously mentioned, that it is only in the amount of oxygen that there is a pronounced difference in the Disco plateau and the Hellefiskebanks.

e. The Atlantic Water in Davis Strait originating from the warm and salt Water in Denmark Strait.

Off the west coast of Greenland, at depths of c. 500 meters, we find a water-layer having a temperature of c. 4° and a salinity of c. 34.95 ‰. This water layer passes through Davis Strait over the ridge

and penetrates into Baffin Bay where it is diluted with the other waters occurring there, but south of the ridge its temperature and salinity are fairly constant.

Table 8 gives the temperature, salinity and oxygen at the depth where the temperature is maximum at certain stations in the area mentioned. The stations lie near or outside the 1000 meter curve from the latitude of Cape Farewell to that of Godthaab.

Table 8.

Station	N. Lat.	W. Long.	Depth in the sea m.	Maximum Temperature			
				Depth m.	Temp. $t°$	Sal. S ‰	Oxygen O_2 sat %
VI. 20	64°45′	55°29′	920	700	3.90	34.92	(88)
VII. 21	63°56′	53°30′	1090	500	.85	.92	92
VI. 18	56′	23′	930	600	.92	.94	91
VI. 8	56′	23′	> 1050	800	.83	.94	92
VII. 8	13′	52°55′	> 1100	500	4.22	.97	96
VI. 7	08′	40′	> 700	700	3.94	35.01	(93)
VI. 6	61°47′	53°43′	> 3000	300	4.03	34.94	93
VII. 9	47′	52°55′	3020	150	.66	.96	(95)
VI. 5	60°13′	49°52′	2650	200	3.96	.99	91
			Mean...	494	4.03	34.95	92

The intermediate Atlantic water in Davis Strait is thus principally found at depths of c. 500 meters with a temperature of 4°.0 and a salinity of 34.95 ‰. The mean oxygen content is 92 % and thus shows a slight subsaturation owing to the exclusion of the water from the atmosphere during its passage from Denmark Strait into Davis Strait.

3. The Mixture of the Components of the Water found in Davis Strait.

In order to obtain a general view of the intermixing of the water masses mentioned in the preceding chapter, we shall make use of graphical representation of the material by means of TS-diagrams[1]) according to the method used by Helland Hansen, A. Merz, J. P. Jacobsen and others.

The diagrams given in figs. 3, 4, 5 and 6 comprise the same areas as were mentioned in chapter 1, and in each diagram are plotted all observations from the area taken during the expeditions of the "Dana" in 1925 and from the "Islands Falk" in the same year. In plotting the observations from the different depths a distinction has been made between observations from the surface to 50 meters inclusive, from depths greater than 50 meters to 150 meters inclusive, and from depths greater than 150 meters to the greatest depths, as indicated in the diagrams.

For comparison of the water masses actually found at the different depths and the water masses which may have arisen from the intermixing of the water masses mentioned in chapter 1, these latter have also been plotted in the diagrams. The Atlantic water determined by the mean values in table 8 at c. 500 meters is represented by the point *A*, and the cold water masses determined by the mean values

[1]) See e. g. J. P. Jacobsen, Contribution to the Hydrography of the North Atlantic. The "Dana" Expedition 1921—22. Copenhagen 1929.

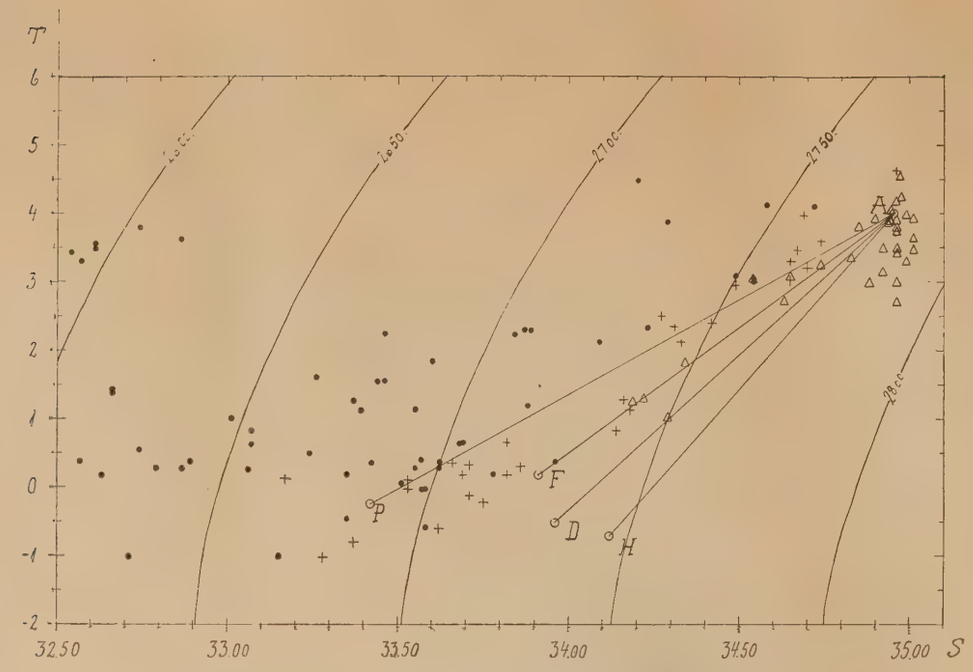

Fig. 3. TS diagram for the stations in the area between 60°0′ and 63°30′ N. Lat.
• indicates temperatures and salinities at depths between 0 and 50 m.
+ — — - — - — — 50 - 150 m.
△ — — - — - — of more than 150 m.

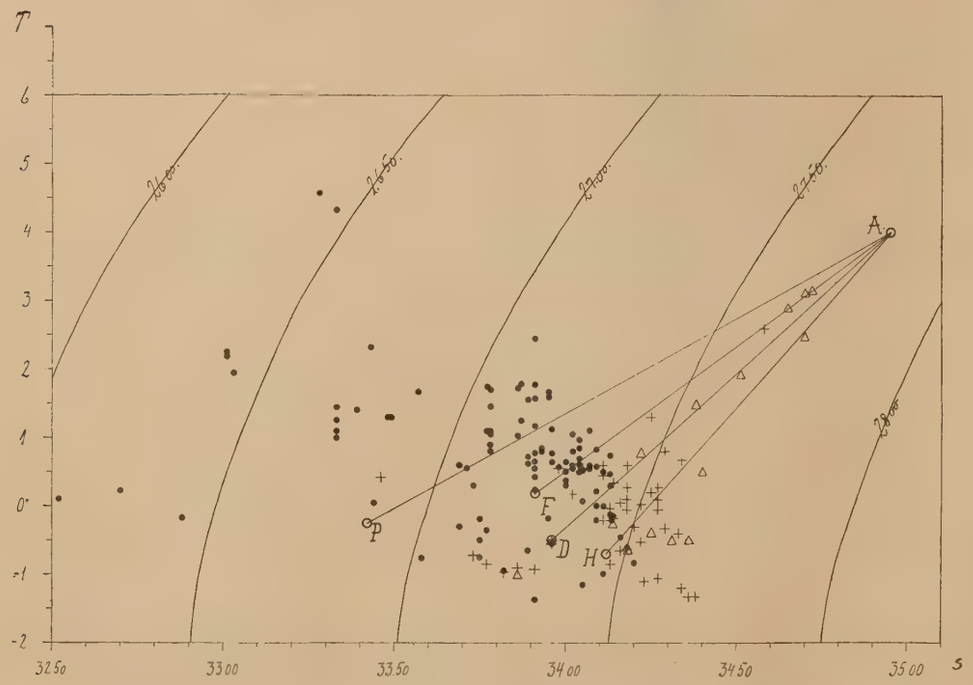

Fig. 4. TS diagram for the stations in the area between 65°0′ and 68°30′ N. Lat.
• indicates temperatures and salinities at depths between 0 and 50 m.
+ — — - - - — — 50 - 150 m.
△ — — - — - — of more than 150 m.

in tables 2, 4, 6 and 7 are represented respectively by *P*, *H*, *F* and *D*, *P* indicating cold water from the Polar current, *H* cold water from the Hellefiskebanks, *F* cold water in the neighbourhood of Fyllas bank, and *D* cold water from the Disco plateau. The water masses possibly formed by the mixing of the Atlantic water with the different kinds of cold water are then indicated by the points on the straight lines connecting *A* with the points *P*, *H*, *F*, and *D*. Such lines are drawn in all the diagrams figs. 3—6.

The diagrams further show some isopycknical lines marked with the value of σ_t.

From the scattered distribution of the points representing water from a depth less than or equal to 50 meters, it will be seen that the temperature and salinity of the upper layer are very variable. The discussion of the character of this water, which contains much water from the melting ice, can only be given in connection with the chart showing the temperature and salinity at the surface (see p. 23).

For depths greater than 50 meters we find some regularity in all the diagrams in the distribution of the points indicating a mixture to some extent of Atlantic water at c. 500 meters with cold water at c. 50—100 meters.

As mentioned above, the cold water found in the area between 60° and 63°30′ N. Lat. may be presumed to originate in the main from the Polar current in which the salinity is relatively low. From the diagram in fig. 3 it is seen that the points representing water from depths from 50 meters to 150 meters lie near the line *AP*, and the water from these depths can thus be assumed to have been formed mainly by the intermixing of water from the Polar current with Atlantic water. Some points in the diagram in fig. 3 show a deviation from the line *AP* which may possibly be accounted for by the influence of local winter cooling.

As will be seen from the diagram, the Atlantic water ($t = 4°03$, $S = 34{,}95\,‰$) is very predominant in the area, and at the greatest depths at which measurements have been made (down to 2350 meters) none of the water shows much difference from the intermediate Atlantic water.

The area from 65° to 68°30′ N. Lat. drawn in fig. 4 presents somewhat of a contrast to the above-mentioned area. Here the points representing mixed water lie at a greater distance from the line *AP* and nearer to the line *AH*.

In this area we may assume a mixing of the cold water from the banks, represented by the point *H*, with the penetrating Atlantic water, or possibly with some water formed by the mixing of Atlantic water with water from the Polar current.

In the latter case we should anticipate a distribution of the points along a broken line consisting partly of the righthand part of the *AP* line and a line (or belt) joining the point *H* with the *AP* line. Possibly something similar is actually the case, but the intermixing of the different kinds of water seems to be so complicated that it is not possible to draw any trustworthy conclusion in this way. It must be noted that the Atlantic water determined by the point *A* and found to be predominant in the southernmost area only reaches the area mentioned here diluted with cold water, probably of various origin.

Having dealt with the southernmost area and the above-mentioned area containing the Hellefiskebanks, we shall now consider the area lying between them, containing Fyllas bank. The diagram for this area is given in fig. 5. It will be seen that conditions here occupy an intermediate position between those of the first-mentioned areas. The Atlantic water is predominant and so also are mixtures of this with water from the Polar current. This, however, is only the case at greater depths, say more than 200 meters. At smaller depths we may assume that a mixing of different kinds has taken place, and it would seem that locally formed cold water is rather predominant.

Finally we shall mention the waters occurring in the northernmost area from 68°30′ to 70° N. Lat. It will be seen from the diagram in fig. 6 that conditions here are somewhat similar to those in the area containing the Hellefiskebanks. Only diluted Atlantic water occurs in the area, and the mixing of this with cold water gives the same picture as in the southern area.

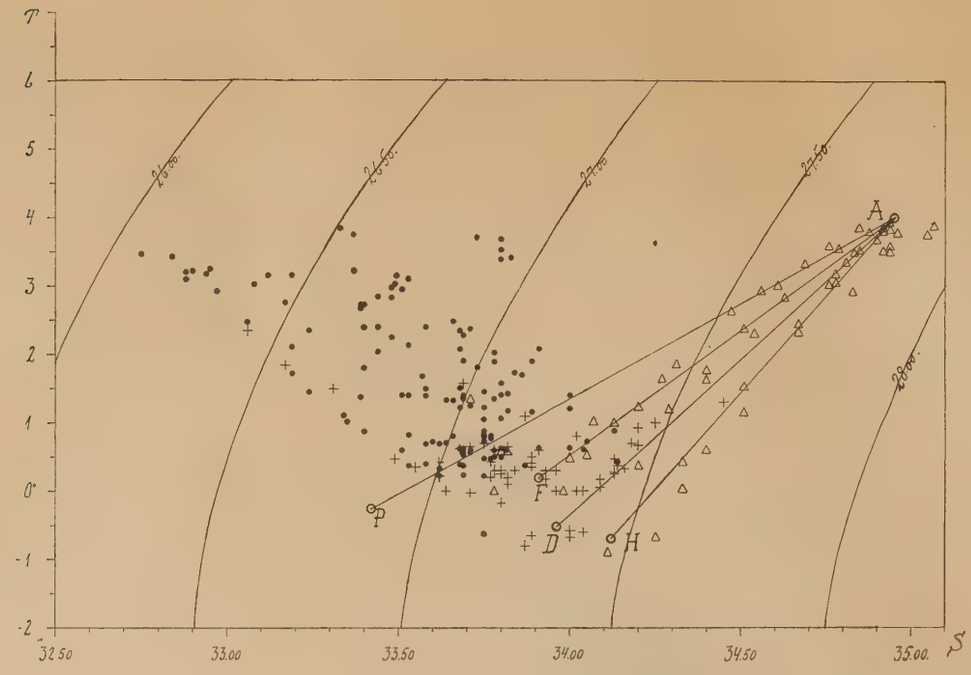

Fig. 5. TS diagram for the stations in the area between 63°5′ and 65°30′ N. Lat.
• indicates temperatures and salinities at depths between 0 and 50 m.
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△ — — - — - — of more than 150 m.

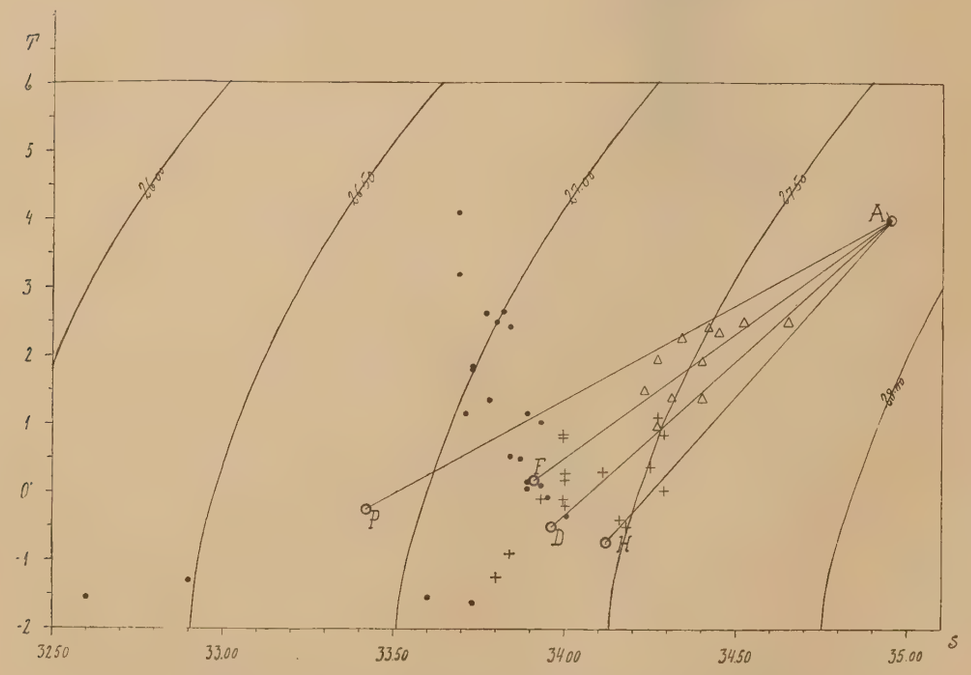

Fig. 6. TS diagram for the stations in the area between 68°5′ and 70°30′ N. Lat.
• indicates temperatures and salinities at depths between 0 and 50 m.
\+ — — - — - — — 50 - 150 m.
△ — — - — - — of more than 150 m.

4. Discussion of the Sections and Charts.

a. Sections in the Atlantic off Iceland and Greenland.

As shown in fig. 1 observations are at hand from two sections in the Atlantic off Iceland and Greenland; the southernmost of these sections dates from the end of May and the beginning of June and the northernmost from the latter part of July. The sections are given in figs. 7 and 8. In fig. 7 is seen the well-known difference between the waters south of Iceland and those south of Greenland, and the transition between them. A glance at the oblique position of the isotherms and isohalines in the part of the section lying close to the west of the ridge of Reykjanes might convey the impression that strong currents existed here. This is not the case because low temperature is connected with low salinity and vice versa, and this accounts for the fact that there are, in reality, only small differences in the specific gravity in this part of the section.

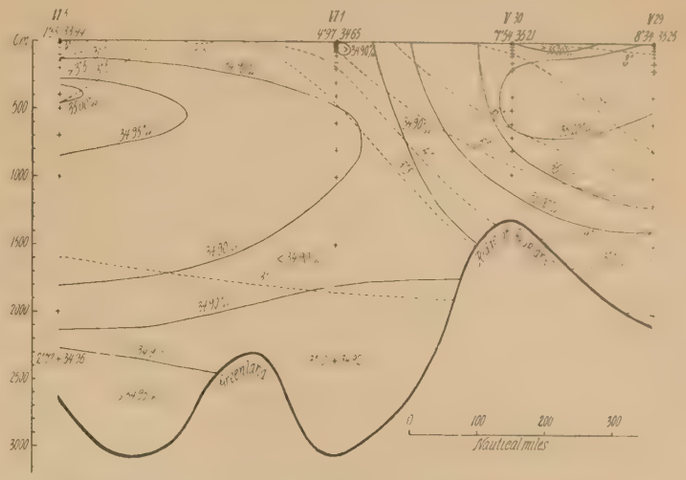

Fig. 7. Section south of Iceland and Greenland (see fig. 1).

South and south-west of Greenland at a depth of c. 500 meters we find the central part of a fairly uniform water mass consisting of Atlantic water somewhat diluted with water of low temperature and salinity. In chapter 1 this water has been characterised by the temperature 4°02 and the salinity 34.95 ‰. It may be supposed to have its origin mainly from the Irminger current.

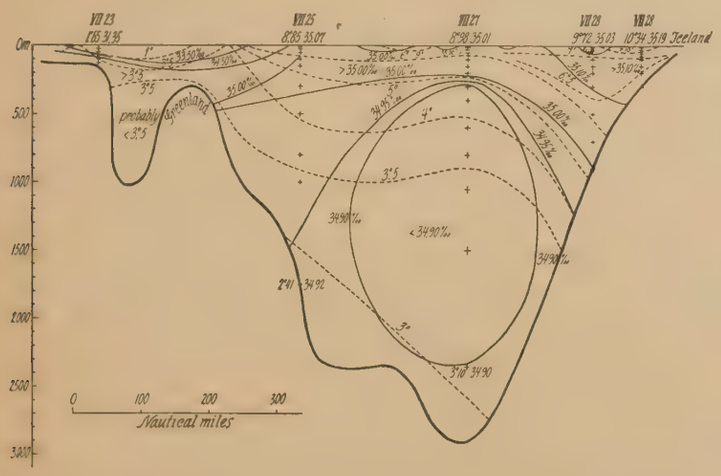

Fig. 8. Section from Iceland round the south end of Greenland (see fig. 1).

At such great depths as 2000 meters or more we find water with a temperature and salinity not very different from those of the bottom water in the Atlantic. Thus we have:

	VI. 5	VI. 1	V. 29
Depth	2350	2350	2000
Temp.	2.72	3.10	3.00
Sal.	34.96	34.92	34.97

As is generally known, F. NANSEN[1]) concluded from earlier observations that the bottom water of the Atlantic is formed by the sinking of the surface water in an area south and south-east of Greenland. In good accordance with the conditions found here the area set out by NANSEN off the south coast of Greenland is somewhat more southerly than the section mentioned here, whereas station VI. 1 of the section lies close to the east of the eastern part of the area determined by NANSEN. The northern section, fig. 8, also shows the marked difference between

[1]) FRIDTJOF NANSEN: Das Bodenwasser und die Abkühlung des Meeres. Internat. Revue der gesammten Hydrobiologie und Hydrographie, Bd. V, Nr. 1. Leipzig 1912.

the waters off Iceland and those off Greenland, but as the section especially off Iceland lies more to the northward, the fairly uniform water mass from c. 100 to 400 meters' depth off Iceland has a lower temperature and salinity than the water south of Iceland found in the southern section. As is well known, an anticyclonic water movement travels round Iceland from the waters south of this island, but during this movement the water is diluted with some cold water. At the surface we find the rather high temperature 10°34 at station VII. 28 nearest the island, the water being heated by the atmosphere in the summer. As seen from the chart in fig. 1, the western part of the section mentioned here runs round the coast of Greenland. At station VII. 25 off the coast of Greenland we find the waters of the Irminger current extending to depths of 500 meters or more. The temperature of the water in the current is 4° to 6°, apart from the upper layer which is heated to c. 9° by the atmosphere. The salinity approaches 35 ‰.

Nearer the east coast of Greenland the Irminger current is covered by the Polar current and the coast water, an this is even the case with the continuation of the Irminger current in the waters southwest of Greenland, as will be seen from fig. 8.

At great depths conditions in the northern section are similar to those of the southern section.

b. Sections off the southern Part of the West Coast of Greenland from c. 62° to c. 70° N. Lat.

Among the sections which can be laid through the different stations shown in fig. 2 we shall first mention the section along this part of the coast at a distance from it of c. 100 miles, and 5 sections across to the coast. The positions of the sections are marked in fig. 2, and in figs. 9—14. The sections show the distribution of temperature and salinity and the longitudinal section shows, in addition, the oxygen content.

In the chart in fig. 2 and in these sections in figs. 9—14 all stations have, as usual, been marked with the date at which the observations were taken. For all the sections except that across the coast in the southernmost part of the area the observations were taken in June.

The longitudinal section shows the variation of the temperature and salinity in accordance with the distribution already stated of the different kinds of water. At c. 50 meters we find a temperature minimum between the isotherms of 1. degree.

In the southern part of the section this minimum belongs to the water influenced by the East-Greenland Polar current and does not sink below 0 degrees, whereas the minimum in the northern part of the area belongs to the northern intermediate cold water with temperatures down to c. —1°5 degrees. Water with temperatures below 0 degrees is hatched in these and the following figures. In the deeper strata of the section we find an admixture of Atlantic water, which makes its influence felt through the whole section. It is interesting that, as will be seen in the figure, the oxygen content of the Atlantic water decreases in a northerly direction owing to the fact that the water is shut off from the atmosphere. In the northernmost part of the section the oxygen content goes down to c. 70 % of the amount necessary for saturation.

In figs. 10—14, representing the cross sections, the situation of these is given in relation to the different banks off the coast. Outside the banks the distribution of temperature and salinity known from the afore-mentioned longitudinal section is also shown in these sections. Of special interest are the features shown in the figure representing conditions inside the banks or near the coast. Thus for instance fig. 12, representing the section at the great Hellefiskebank, shows how the cold water covers the bottom at the bank and how it sinks down in the area inside the bank. No admixture of Atlantic water is found here.

To illustrate the variations of the hydrographical conditions on the banks and in the deep water around them, the sections across Fyllas bank dating from $^{8}/_{6}$—$^{9}/_{6}$, $^{4}/_{7}$—$^{5}/_{7}$ and $^{21}/_{7}$ and shown in

figs. 15—17 can be used. In the first section, dating from the beginning of June, the cold water with a temperature below 0 degrees appears at c. 100 meters outside and inside the bank. At the beginning of July

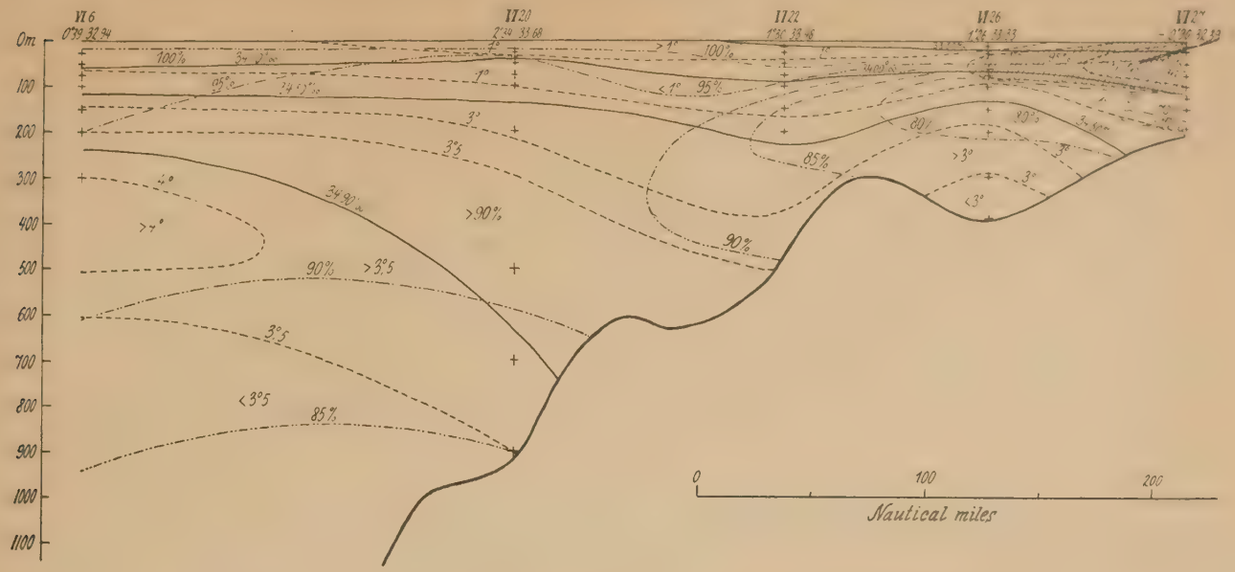

Fig. 9. Section I west of Greenland in a north-southerly direction outside the banks (see fig. 2).

temperatures below 0 degrees have disappeared inside the bank, and on July 21st the temperature has also risen above 0 degrees outside the bank. At the same time from $^{8}/_{6}$ to $^{21}/_{7}$ the surface temperature by the bank has risen c. 3 degrees owing to the influence of the atmosphere and the sun.

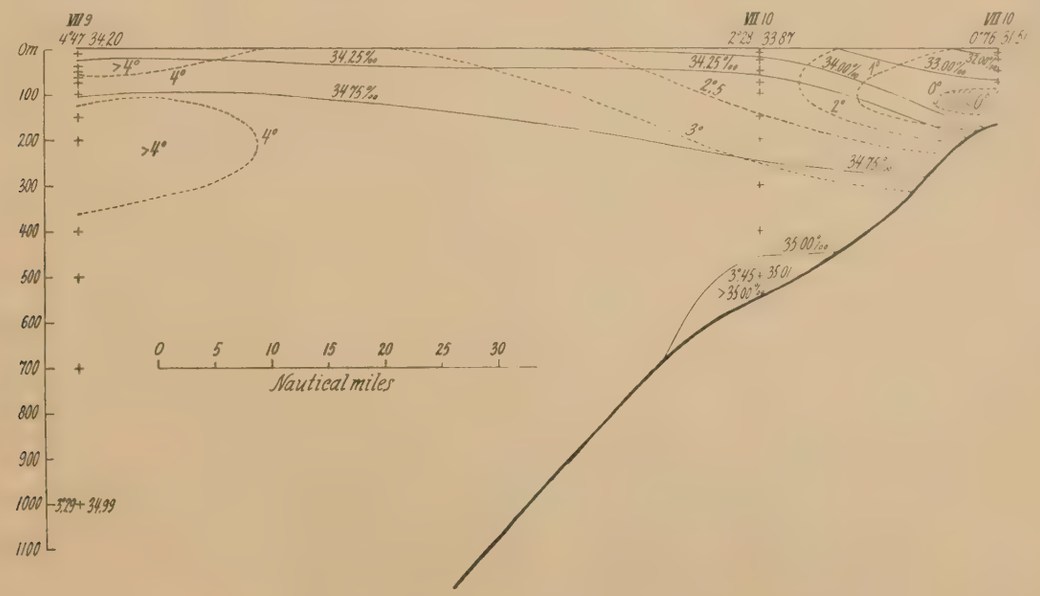

Fig. 10. Section II across the coast of Greenland at "Frederikshaab" (see fig. 2).

In order to furnish another illustration of the variations in temperature and salinity at Fyllas bank during the period mentioned above, we have also constructed the diagrams in fig. 18 marked a—c,

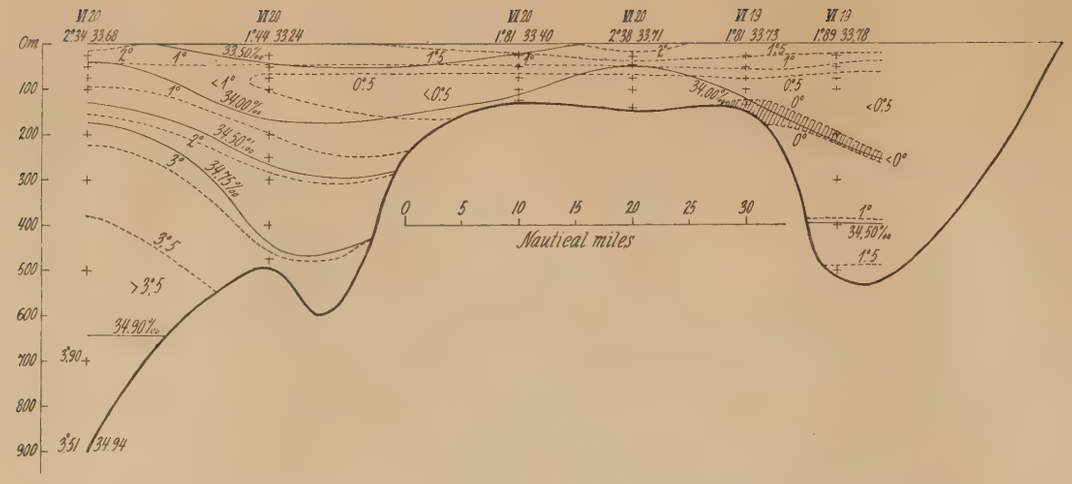

Fig. 11. Section III across the coast of Greenland over "Lille Hellefiskebanke" (see fig. 2).

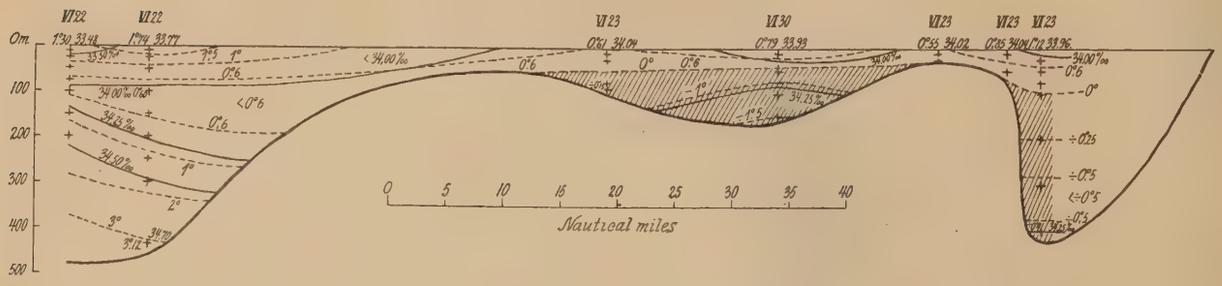

Fig. 12. Section IV across the coast of Greenland over the southern part of "Store Hellefiskebanke" (see fig. 2).

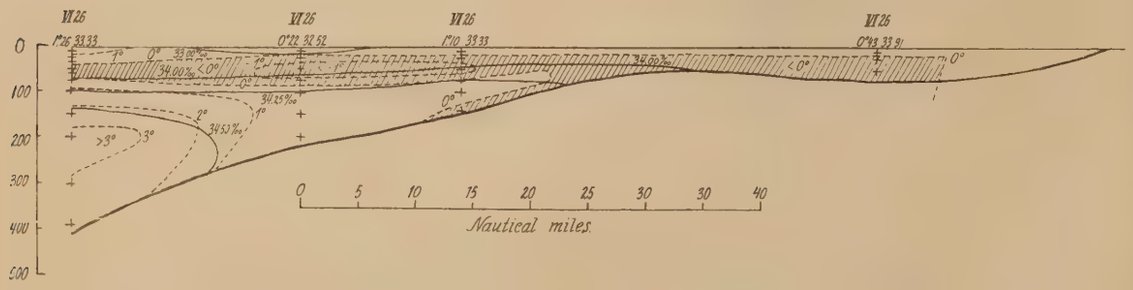

Fig. 13. Section V across the coast of Greenland over the northern part of "Store Hellefiskebanke" (see fig. 2).

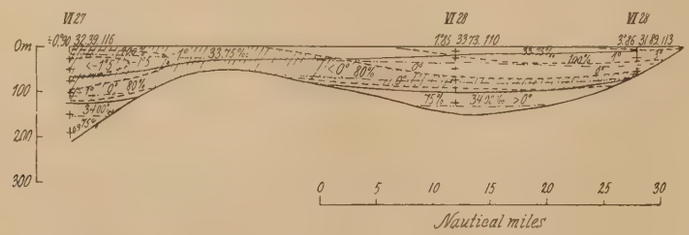

Fig. 14. Section VI across the coast of Disco (see fig. 2).

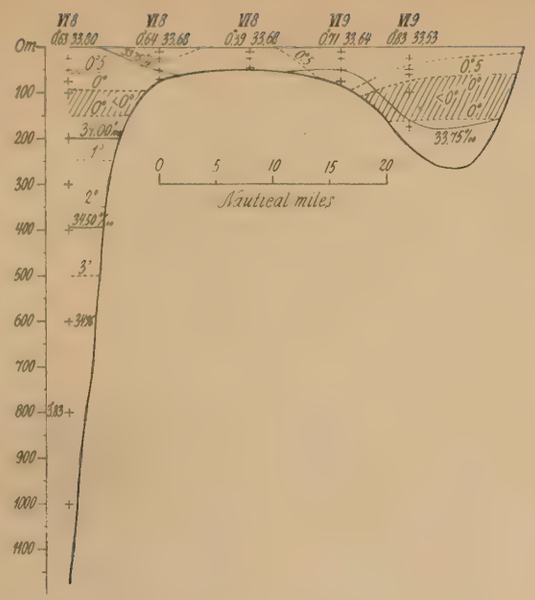

Fig. 15. Section VII a across the coast of Greenland over "Fyllas Banke" (see fig. 2).

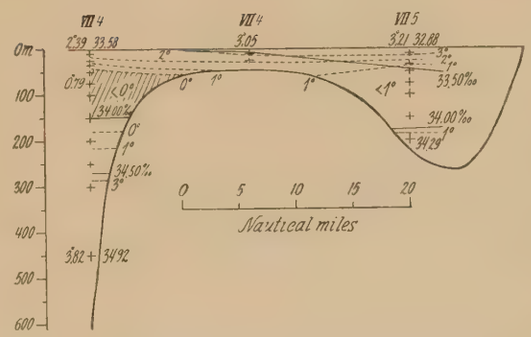

Fig. 16. Section VII b across the coast of Greenland over "Fyllas Banke" (see fig. 2).

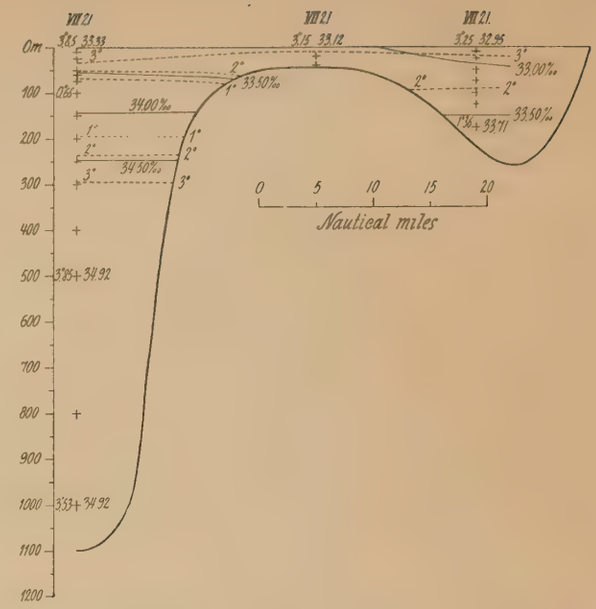

Fig. 17. Section VII c across the coast of Greenland over "Fyllas Banke" (see fig. 2).

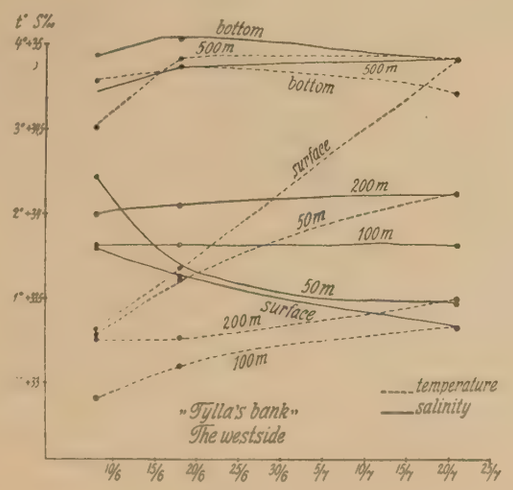

Fig. 18 a.

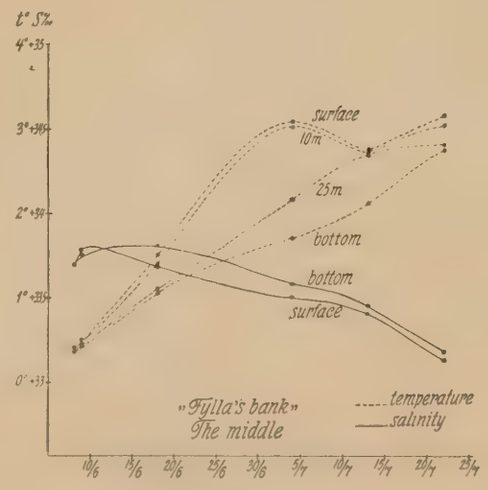

Fig. 18 b.

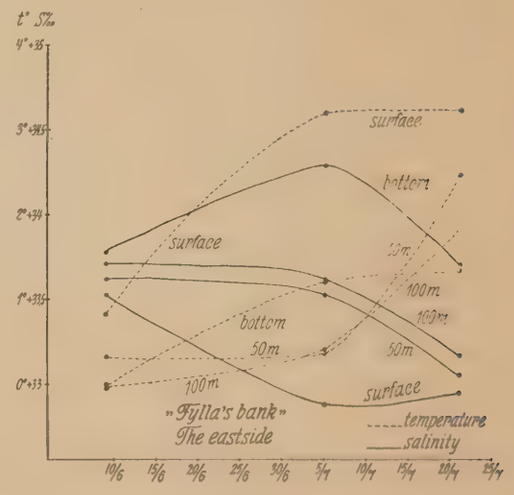

Fig. 18 c.

Fig. 18. Diagrams from different places of "Fyllas Banke", indicating the variations of temperature and salinity with the time.

from different places near the bank. The curves in the diagrams indicate the variation of temperature and salinity with the time at the depths stated on the curves, fig. 18 a referring to the western side of the bank, 18 b to the middle, and 18 c to the eastern side of the bank.

It will be seen from the diagrams that at the middle of the bank (fig. 18 b) the temperature rises at the surface as well as at the bottom (45 m.) during the time considered. Some fluctuations at the

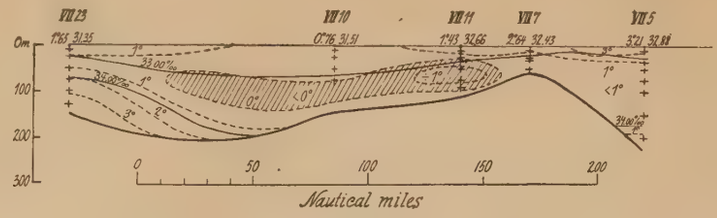

Fig. 19. Section VIII along the coast of Greenland from the southernmost part of it to "Godthaab" (see fig. 2).

surface may be accounted for by changes in the air temperature. At the bottom the rise of the temperature is nearly linear. The salinity decreases during the same space of time and is practically the same from the surface to the bottom.

In the channel at the eastern side of Fyllas bank the diagram 18 c shows that the temperature and salinity at the different depths have been subject to fairly large fluctuations. On the 8th of June

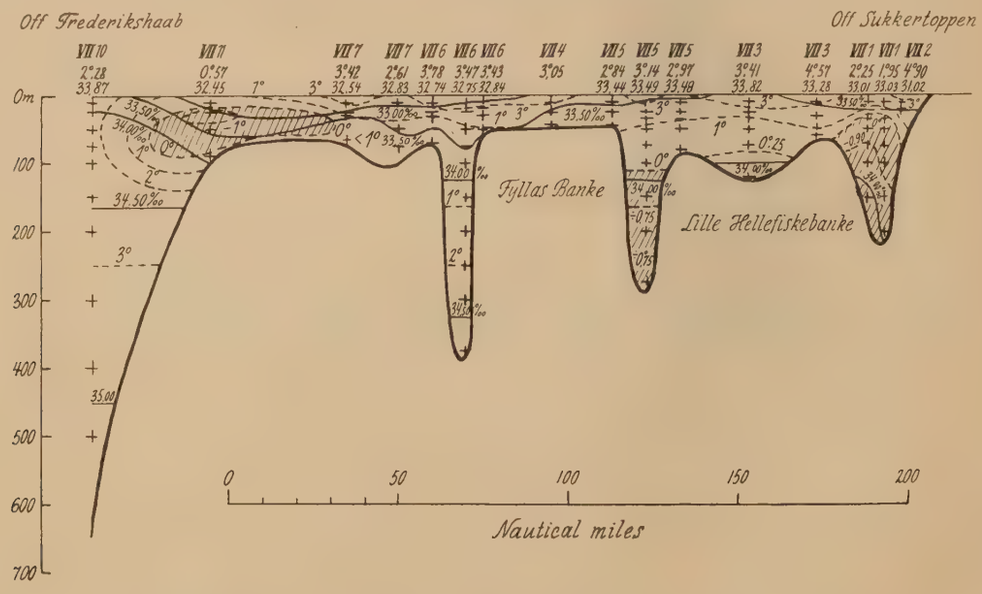

Fig. 20. Section IX along the coast of Greenland from "Frederikshaab" to "Sukkertoppen" over the banks (see fig. 2).

an intermediate water layer with a salinity of c. 33.75 ‰ and a low temperature (in minimum −0°04) was found at the depths between 50 and 150 meters, that is, almost the same as the characteristic temperature and salinity of the cold water layer mentioned as *F* (see table 6 and diagrams 3—6). Four weeks later on the 5th of July the hydrographical conditions were found to be somewhat altered. The temperature had increased at all depths but only to a slight degree at the intermediate depths 50—150 meters. Later again, on the 21st of July, the temperature had increased at all depths, and the intermediate cold temperature had disappeared. The variations of the salinity in the channel at the eastern

side of the bank on the whole showed a decrease for the surface and intermediate layer at 50—150 meters. In the bottom layer the highest salinity was found in the middle of the period considered. The decrease of the salinity in the upper layers can be accounted for by the influence of the fresh water from the firths, and the disappearance of the low temperature and decrease of salinity in the intermediate water-layer by the intermixing with the water in the upper layers.

The diagram showing the conditions at the western side of the bank is based on the observations from the stations which were taken on the 8th and the 18th of June and on the 21st of July. The stations all lie in 63°56′ N. Lat., those dating from the 8th and the 18th of June in 53°23′ W. Long. and the station from the 21st of July in 53°30′ W. Long. The slight difference in the longitude of the stations may possibly account for some difference in the hydrographical conditions. In considering the diagram in fig. 18 a, based on the three stations on the western side of Fyllas bank, this difference will, however, be disregarded. As on the bank and at its eastern side, at the western side, too, we find a rise of the temperature in the upper layers during the time considered. At the surface the salinity decreases slightly. The intermediate layer at c. 50—150 meters shows the same temperature and salinity as the aforementioned *F*-water (see table 6 and diagrams 3—6). As a difference from what was the case at the eastern side of the bank it is to be noted that the temperatures of the intermediate layer at the western side of the bank only increase very slightly during the period mentioned. At a depth of 500 meters we find almost unmixed Atlantic water with only a small variation in temperature and salinity.

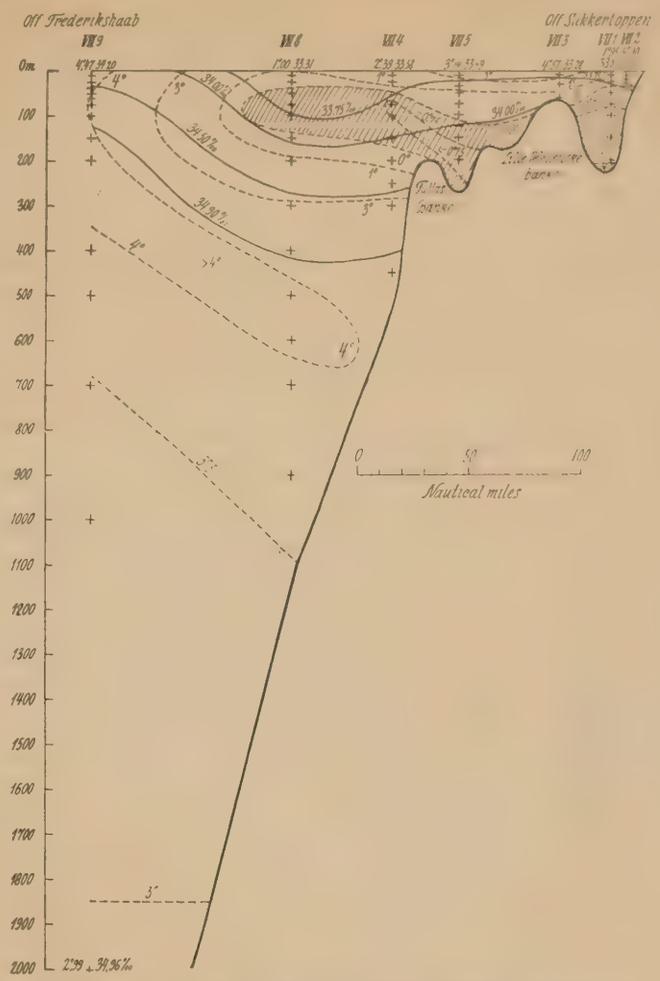

Fig. 21. Section X along the coast of Greenland from "Frederikshaab" to "Sukkertoppen", the southern part outside the banks (see fig. 2).

In order to give some more details about the conditions near the coast where observations have been taken, figs. 19—22 show the sections along the coast marked in the usual way on the chart in fig. 2. Finally fig. 23 shows a section across the coast south of Fyllas bank at c. 63° N. Lat. Looking through the sections figs. 9—17 and 19—23 we find that especially in fig. 11 and fig. 21 the isotherms and isohalines slope in the vicinity of the continental shelf. This position of the curves indicates that in these areas the current must be rather strong, and the water of less salinity and therefore less specific gravity being nearest the shelf, we must expect a component of the current in a westerly direction between the stations VII 8 (63°13′, 52°55′) and VII 9 (61°47′, 52°55′) and a component of the current in a northerly direction between the stations VI 20 (64°45′, 54°56′) and VI 20 (64°45′, 55°29′) (see fig. 2).

To form an estimate of the velocity of these components of the current, we have found the differences between the dynamic depths for different pressures, as given below, for the two pairs of stations.

It will be seen from the table that the increase of the differences with the depth is most rapid in the upper 200 or 300 meters at both pairs of stations, and if we take it for granted that the move-

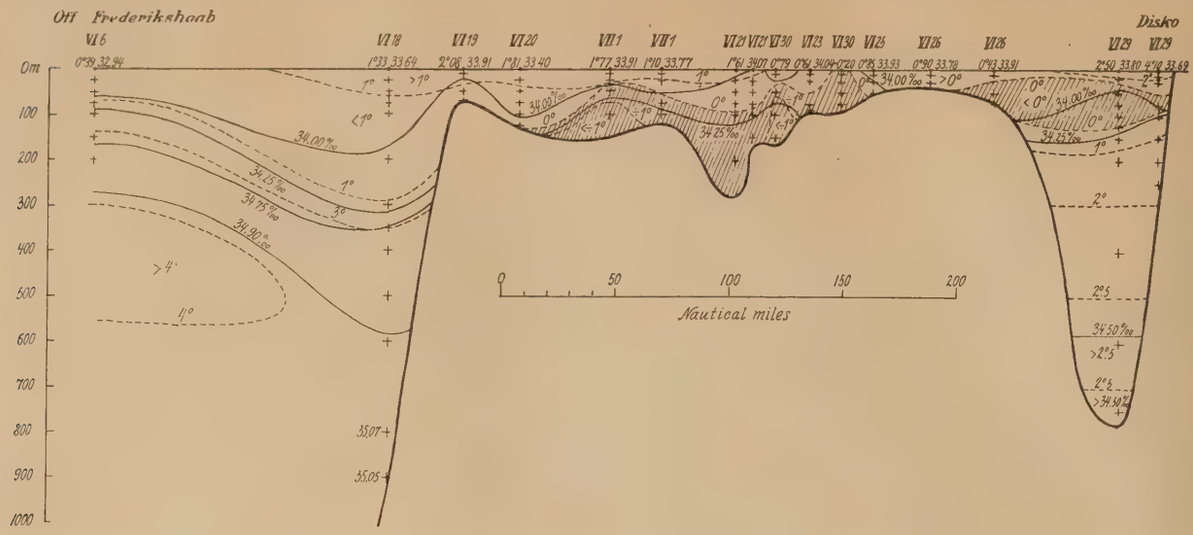

Fig. 22. Section XI along the coast of Greenland from "Frederikshaab" to Disco (see fig. 2).

ments of the water at the greatest depths where measurements have been taken are but slow compared with the movements in the upper strata, we find, according to the method of Bjerknes, the current com-

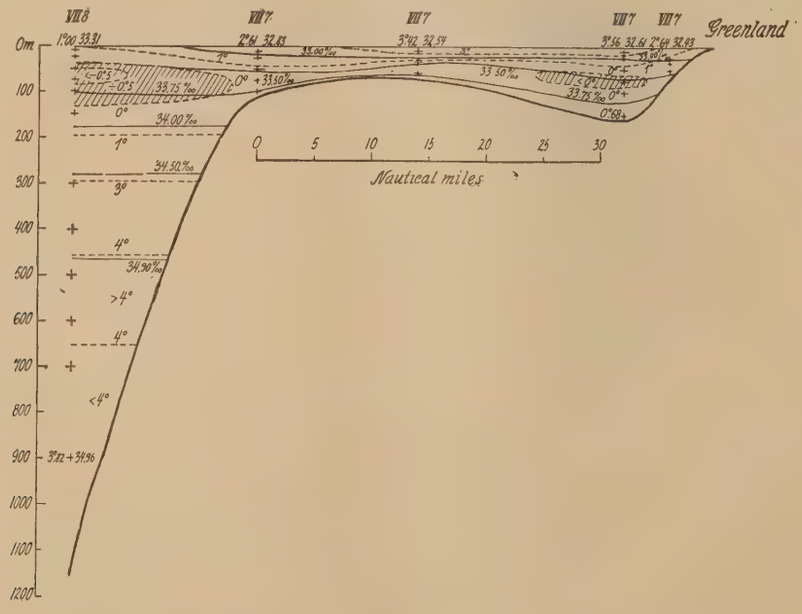

Fig. 23. Section XII across the coast of Greenland south of "Fyllas Banke" (see fig. 2).

ponents at the surface across to the sections by the formula

$$v = 37.1 \frac{h}{l \sin \varphi}$$

where v is the velocity in cm./sec, h the difference between the dynamic depths expressed in dynamic cm.

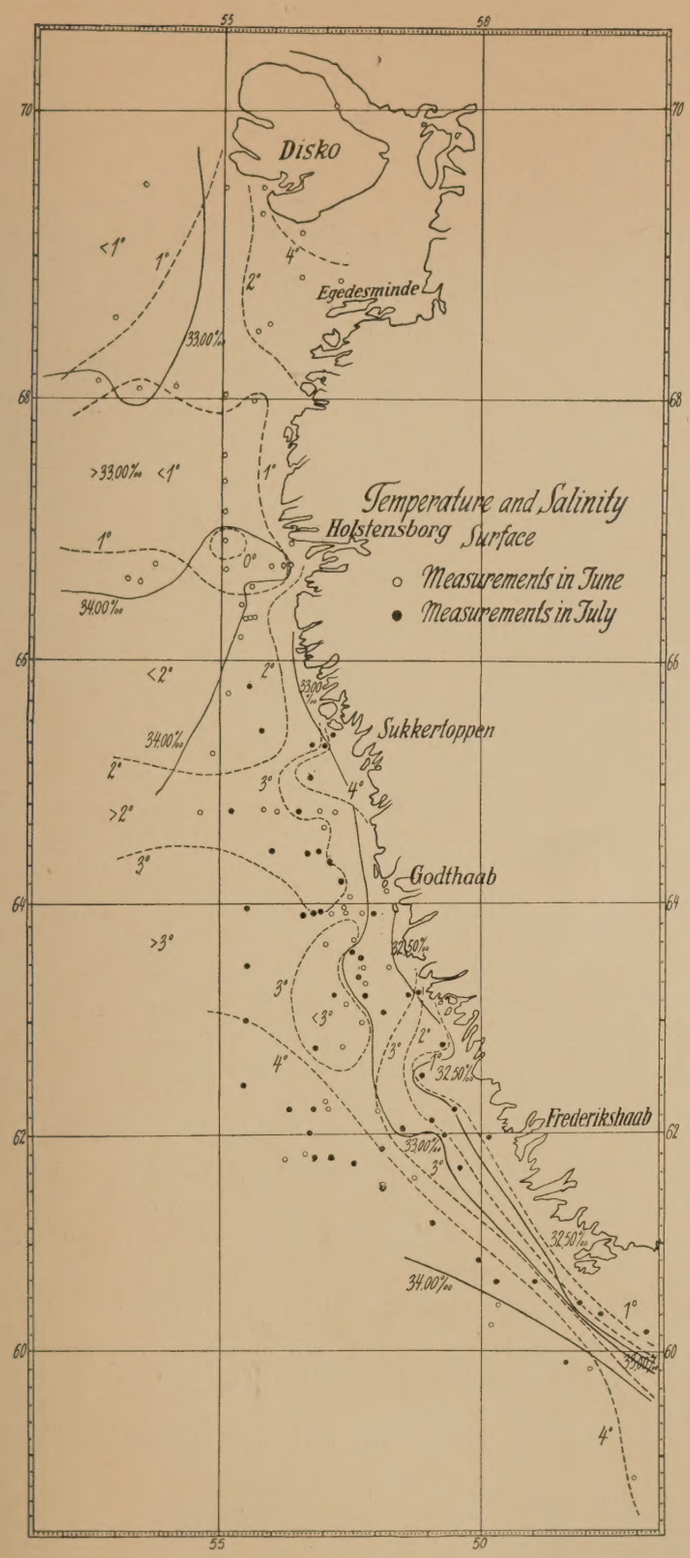

Fig. 24. Temperature and salinity of the surface in June and July. The charts contain all the measurements from the "Dana" and those taken from the "Islands Falk" by Riis Carstensen and also the observations taken in 1925 from the steamers of "Danske grønlandske Handel".

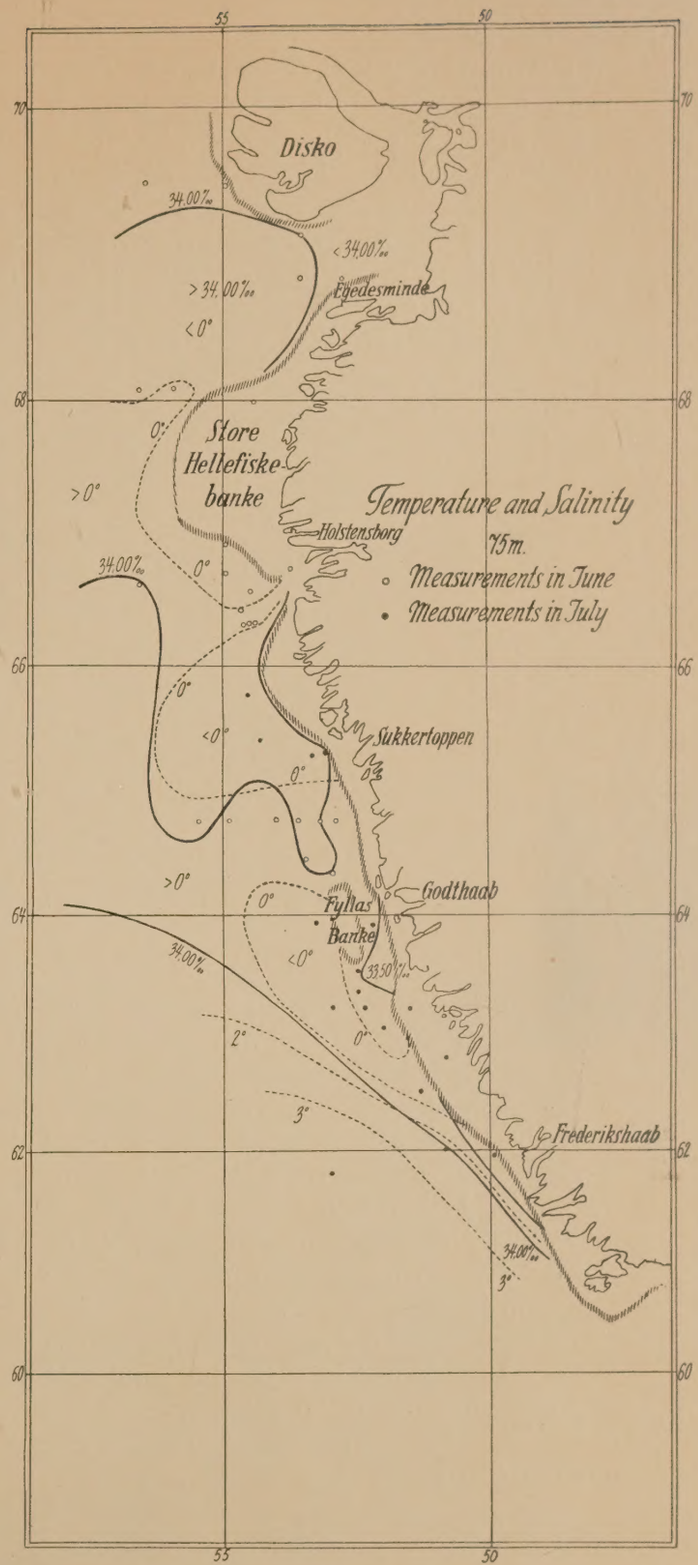

Fig. 25. Temperature and salinity at a depth of 75 m. in June and July. The chart contains the stations taken by the "Dana" and one station from the "Islands Falk" by Riis Carstensen. The signature ▬ indicates the depth of 75 m.

for a given pressure in the deepest strata, l the distance in miles between the two stations in question, and φ the average of their latitudes.

In this way we find the current components for the surface given at the bottom of the table. Their values and their directions seem to be in good accordance with what is known and also found on the basis of the measurements from the "Dana" in 1925, but of course the actual figures for the velocities can only be accepted with a good deal of reservation.

Pressure in Deci-Bars	Differences in cm. between dynamic depths at different pressures for the stations given below.	
	63°13′ N. Lat. / 52°55′ W. Long. — 61°47′ N. Lat. / 52°55′ W. Long.	64°45′ N. Lat. / 54°56′ W. Long. — 64°45′ N. Lat. / 55°29′ W. Long.
0	0.0	0.0
10	.4	.3
20	.7	.5
30	1.1	1.0
40	. . .	.4
50	2.1	.8
60	.6	2.1
70	3.1	.4
80	.6	.7
90	4.1	3.0
100	.6	.2
200	8.8	6.6
300	10.9	8.9
400	12.3	9.1
500	.8	.3
600	13.2	
700	.8	
800	14.4	
900	15.0	
	$v = 37.1 \frac{15.0}{86 \sin 62°30'}$	$v = 37.1 \frac{9.3}{14 \sin 64°45'}$
	$v = 7.3$ cm./sec. westward.	$v = 27$ cm./sec. northward.

Below the surface the current must be supposed to decrease with increasing depth, and on this supposition to vanish in c. 500 meters.

Some calculations have also been made for other sections, but owing to the scantiness of the material the results have been of little value. Of course it must also be remembered that the value for the velocity found here only refers to the currents caused by the fields of force in the sea, and disregards the effect of the wind.

In order to obtain a general view of the distribution of temperature and salinity in a horizontal direction in the upper strata we have constructed charts with isotherms and isohalines for the surface and for a depth of 75 meters (figs. 24 and 25). The material used for construction of the surface chart has been taken partly from the material of the "Dana" expedition treated here, among which are found a good many surface observations besides the observations at the stations already mentioned, and partly from surface observations taken by the steamers of "Kgl. grønlandske Handel". All these observations have been published in the Bulletin hydrographique for the year 1925. On the chart in fig. 24 the place of observation is plotted with different signatures for the months of June and July respectively. This should be kept in mind as the isotherms and isohalines have been drawn in accordance with the actual values of temperature and salinity at the different spots, and where the signatures indicate e. g. that the observations are taken in June, the curves also refer to that month.

In the main the curves in the northern part of the area refer to the month of June, and the curves in the southern part of the area to the month of July.

The chart in fig. 25 gives the position of isotherms and isohalines at the depth 75 meters for the time from June 19th to July 11th.

We wish to express our best thanks to cand. A. Lomholt for his valuable assistance in working up the material.

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